CHAPTER 2

VIDEO AND RF AMPLIFIERS

LEARNING OBJECTIVES

Upon completion of this chapter, you will be able to:

1. Define the term "bandwidth of an amplifier."
2. Determine the upper and lower frequency limits of an amplifier from a frequency-response curve.
3. List the factors that limit frequency response in an amplifier.
4. List two techniques used to increase the high-frequency response for a video amplifier.
5. State one technique used to increase the low-frequency response of a video amplifier.
6. Identify the purpose of various components on a schematic of a complete typical video amplifier circuit.
7. State the purpose of a frequency-determining network in an rf amplifier.
8. State one method by which an rf amplifier can be neutralized.
9. Identify the purpose of various components on a schematic of a complete typical rf amplifier.

INTRODUCTION

In this chapter you will be given information on the frequency response of amplifiers as well as specific information on video and rf amplifiers. For all practical purposes, all the general information you studied in chapter 1 about audio amplifiers will apply to the video and rf amplifiers which you are about to study.

You may be wondering why you need to learn about video and rf amplifiers. You need to understand these circuits because, as a technician, you will probably be involved in working on equipment in which these circuits are used. Many of the circuits shown in this and the next chapter are incomplete and would not be used in actual equipment. For example, the complete biasing network may not be shown. This is done so you can concentrate on the concepts being presented without being overwhelmed by an abundance of circuit elements. With this idea in mind, the information that is presented in this chapter is real, practical information about video and rf amplifiers. It is the sort of information that you will use in working with these circuits. Engineering information (such as design specifications) will not be presented because it is not needed to understand the concepts that a technician needs to perform the job of circuit analysis and repair. Before you are given the specific information on video and rf amplifiers, you may be wondering how these circuits are used.

Video amplifiers are used to amplify signals that represent video information. (That's where the term "video" comes from.) Video is the "picture" portion of a television signal. The "sound" portion is audio.

Although the Navy uses television in many ways, video signals are used for more than television. Radar systems (discussed later in this training series) use video signals and, therefore, video amplifiers. Video amplifiers are also used in video recorders and some communication and control devices. In addition to using video amplifiers, televisions use rf amplifiers. Many other devices also use rf amplifiers, such as radios, navigational devices, and communications systems. Almost any device that uses broadcast, or transmitted, information will use an rf amplifier.

As you should recall, rf amplifiers are used to amplify signals between 10 kilohertz (10 kHz) and 100,000 megahertz (100,000 MHz) (not this entire band of frequencies, but any band of frequencies within these limits). Therefore, any device that uses frequencies between 10 kilohertz and 100,000 megahertz will most likely use an rf amplifier.

Before you study the details of video and rf amplifiers, you need to learn a little more about the frequency response of an amplifier and frequency-response curves.

AMPLIFIER FREQUENCY RESPONSE

In chapter 1 of this module you were shown the frequency-response curve of an audio amplifier. Every amplifier has a frequency-response curve associated with it. Technicians use frequency-response curves because they provide a "picture" of the performance of an amplifier at various frequencies. You will probably never have to draw a frequency-response curve, but, in order to use one, you should know how a frequency-response curve is created. The amplifier for which the frequency-response curve is created is tested at various frequencies. At each frequency, the input signal is set to some predetermined level of voltage (or current). This same voltage (or current) level for all of the input signals is used to provide a standard input and to allow evaluation of the output of the circuit at each of the frequencies tested. For each of these frequencies, the output is measured and marked on a graph. The graph is marked "frequency" along the horizontal axis and "voltage" or "current" along the vertical axis. When points have been plotted for all of the frequencies tested, the points are connected to form the frequency-response curve. The shape of the curve represents the frequency response of the amplifier.

Some amplifiers should be "flat" across a band of frequencies. In other words, for every frequency within the band, the amplifier should have equal gain (equal response). For frequencies outside the band, the amplifier gain will be much lower.

For other amplifiers, the desired frequency response is different. For example, perhaps the amplifier should have high gain at two frequencies and low gain for all other frequencies. The frequency-response curve for this type of amplifier would show two "peaks." In other amplifiers the frequency-response curve will have one peak indicating high gain at one frequency and lower gain at all others.

Note the frequency-response curve shown in figure 2-1. This is the frequency-response curve for an audio amplifier as described in chapter 1. It is "flat" from 15 hertz (15 Hz) to 20 kilohertz (20 kHz).

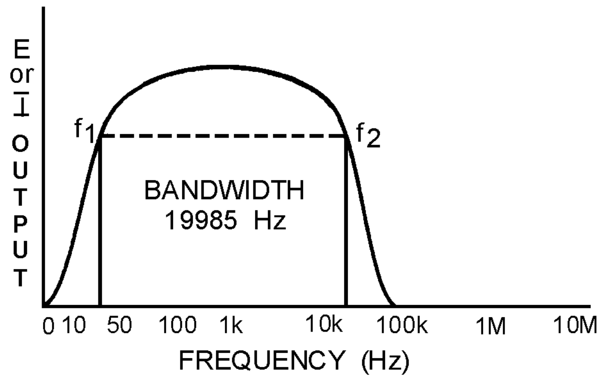


Figure 2-1.—Frequency response curve of audio amplifier.

Notice in the figure that the lower frequency limit is labeled f_1 and the upper frequency limit is labeled f_2. Note also the portion inside the frequency-response curve marked "BANDWIDTH." You may be wondering just what a "bandwidth" is.

BANDWIDTH OF AN AMPLIFIER

The bandwidth represents the amount or "width" of frequencies, or the "band of frequencies," that the amplifier is MOST effective in amplifying. However, the bandwidth is NOT the same as the band of frequencies that is amplified. The bandwidth (BW) of an amplifier is the difference between the frequency limits of the amplifier. For example, the band of frequencies for an amplifier may be from 10 kilohertz (10 kHz) to 30 kilohertz (30 kHz). In this case, the bandwidth would be 20 kilohertz (20 kHz). As another example, if an amplifier is designed to amplify frequencies between 15 hertz (15 Hz) and 20 kilohertz (20 kHz), the bandwidth will be equal to 20 kilohertz minus 15 hertz or 19,985 hertz (19,985 Hz). This is shown in figure 2-1.

Mathematically:

$$BW = f_2 - f_1$$
$$BW = 20\text{ kHz} - 15\text{ Hz}$$
$$BW = 20{,}000\text{ Hz} - 15\text{Hz}$$
$$BW = 19{,}985\text{ Hz}$$

You should notice on the figure that the frequency-response curve shows output voltage (or current) against frequency. The lower and upper frequency limits (f_1 and f_2) are also known as HALF-POWER POINTS. The half-power points are the points at which the output voltage (or current) is 70.7 percent of the maximum output voltage (or current). Any frequency that produces less than 70.7 percent of the maximum output voltage (or current) is outside the bandwidth and, in most cases, is not considered a useable output of the amplifier.

The reason these points are called "half-power points" is that the true output power will be half (50 percent) of the maximum true output power when the output voltage (or current) is 70.7 percent of the maximum output voltage (or current), as shown below. (All calculations are rounded off to two decimal places.)

As you learned in NEETS, Module 2, in an a.c. circuit true power is calculated using the resistance (R) of the circuit, NOT the impedance (Z). If the circuit produces a maximum output voltage of 10 volts across a 50-ohm load, then:

$$\text{True Power} = \frac{E^2}{R}$$

$$\text{True Power} = \frac{(10V)^2}{50\Omega}$$

$$\text{True Power} = \frac{100}{50}\text{watts}$$

$$\text{True Power} = 2\text{ watts}$$

When the output voltage drops to 70.7 percent of the maximum voltage of 10 volts, then:

$$\text{True Power} = \frac{E^2}{R}$$

$$\text{True Power} = \frac{(7.07V)^2}{50\Omega}$$

$$\text{True Power} = \frac{50}{50}\text{watts}$$

$$\text{True Power} = 1\text{ watts}$$

As you can see, the true power is 50 percent (half) of the maximum true power when the output voltage is 70.7 percent of the maximum output voltage. If, instead, you are using the output current of the above circuit, the maximum current is

$$.2\text{amp}\left(\frac{10V}{50\Omega} = .2A\right).$$

The calculations are:

$$\text{True Power} = I^2 R$$
$$\text{True Power} = (.2A)^2 (50\Omega)$$
$$\text{True Power} = (.04)(50)\text{ watts}$$
$$\text{True Power} = 2\text{ watts}$$

At 70.7 percent of the output current (.14 A):

$$\text{TruePower} = I^2R$$

$$\text{TruePower} = (.14A)^2(50\Omega)$$

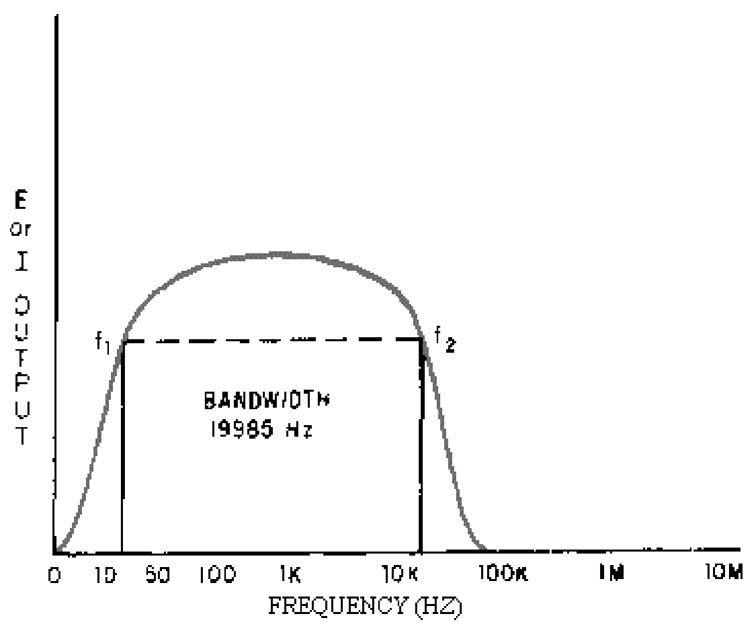
$$\text{TruePower} = (.02 \times 50)\text{watts}$$

$$\text{TruePower} = 1\text{watt}$$

On figure 2-1, the two points marked f_1 and f_2 will enable you to determine the frequency-response limits of the amplifier. In this case, the limits are 15 hertz (15 Hz) and 20 kilohertz (20 kHz). You should now see how a frequency-response curve can enable you to determine the frequency limits and the bandwidth of an amplifier.

READING AMPLIFIER FREQUENCY-RESPONSE CURVES

Figure 2-2 shows the frequency-response curves for four different amplifiers. View (A) is the same frequency-response curve as shown in figure 2-1. View (B) is the frequency-response curve of an amplifier that would also be classified as an audio amplifier, even though the curve is not "flat" from 15 hertz to 20 kilohertz and does not drop off sharply at the frequency limits. From the curve, you can see that the lower frequency limit of this amplifier (f_1) is 100 hertz. The upper frequency limit (f_2) is 10 kilohertz. Therefore, the bandwidth of this amplifier must be 10 kilohertz minus 100 hertz or 9900 hertz. Most amplifiers will have a frequency-response curve shaped like view (B) if nothing is done to modify the frequency-response characteristics of the circuit. (The factors that affect frequency response and the methods to modify the frequency response of an amplifier are covered a little later in this chapter.)



(A)

Figure 2-2A.—Frequency response curves.

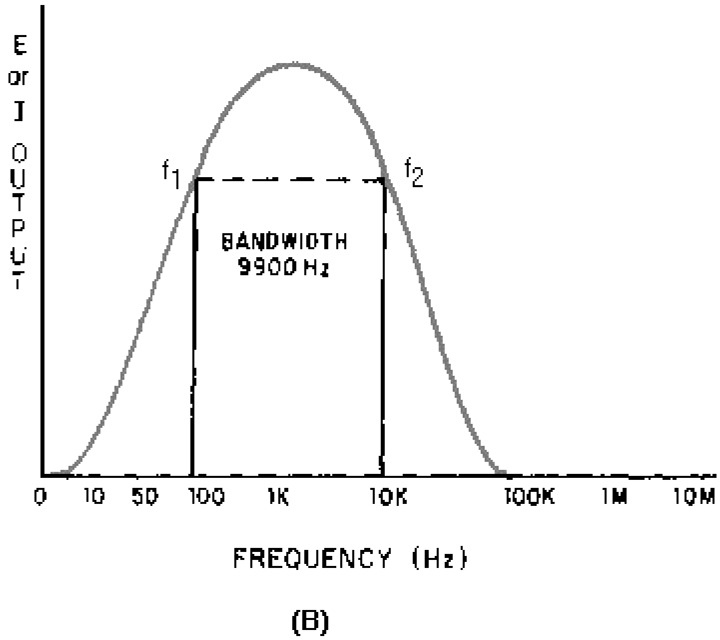


Figure 2-2B.—Frequency response curves.

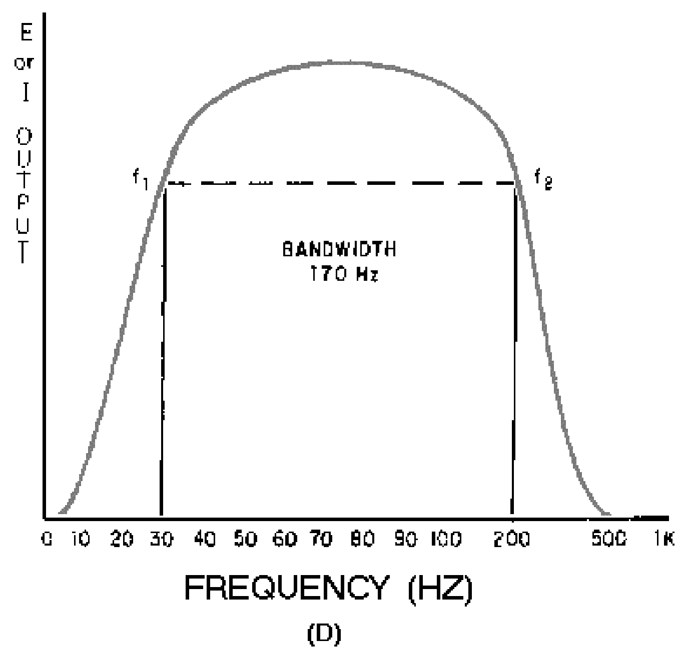


Figure 2-2C.—Frequency response curves.

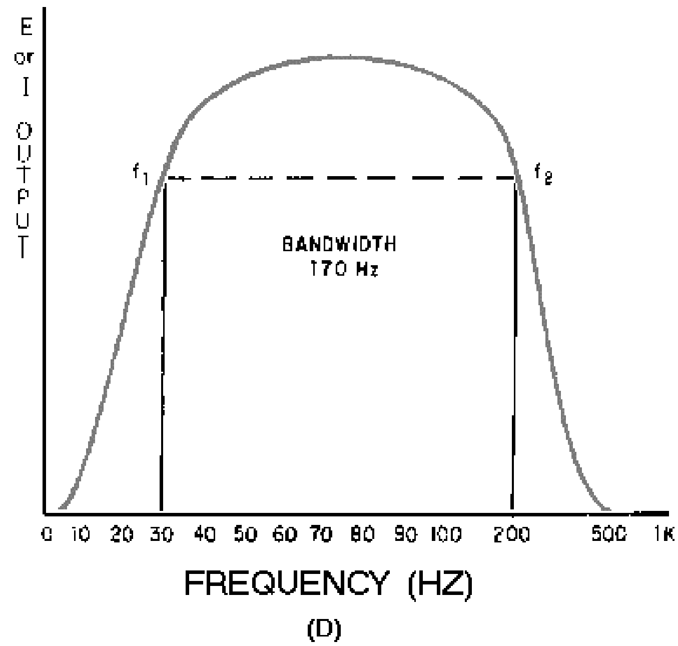


Figure 2-2D.—Frequency response curves.

Now look at view (C). This frequency-response curve is for an rf amplifier. The frequency limits of this amplifier are 100 kilohertz (f_1) and 1 megahertz (f_2); therefore, the bandwidth of this amplifier is 900 kilohertz.

View (D) shows another audio amplifier. This time the frequency limits are 30 hertz (f_1) and 200 hertz (f_2). The bandwidth of this amplifier is only 170 hertz. The important thing to notice in view (D) is that the frequency scale is different from those used in other views. Any frequency scale can be used for a frequency-response curve. The scale used would be determined by what frequencies are most useful in presenting the frequency-response curve for a particular amplifier.

Q-1. What is the bandwidth of an amplifier?

Q-2. What are the upper and lower frequency limits of an amplifier?

Q-3. What are the upper and lower frequency limits and the bandwidth for the amplifiers that have frequency-response curves as shown in figure 2-3?

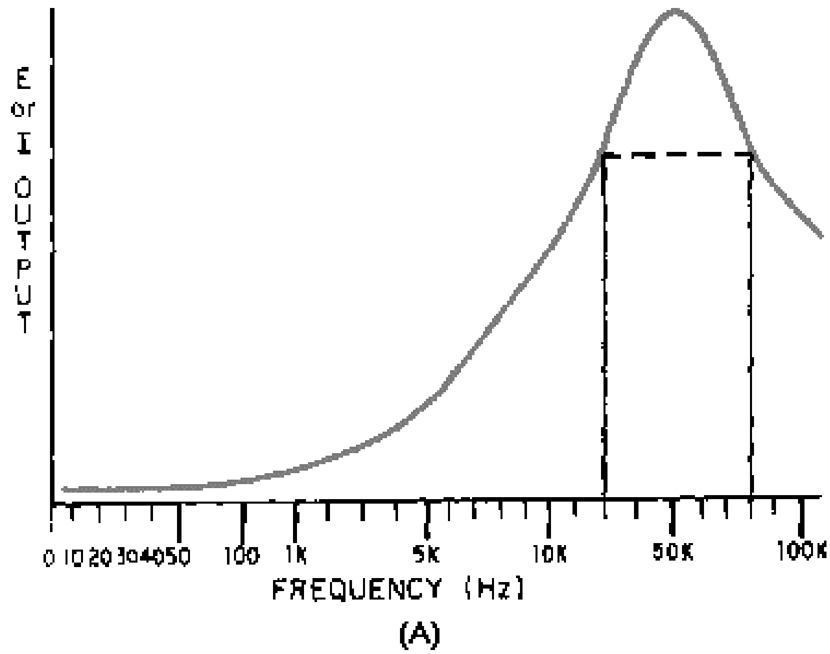


Figure 2-3A.—Frequency-response curves for Q3.

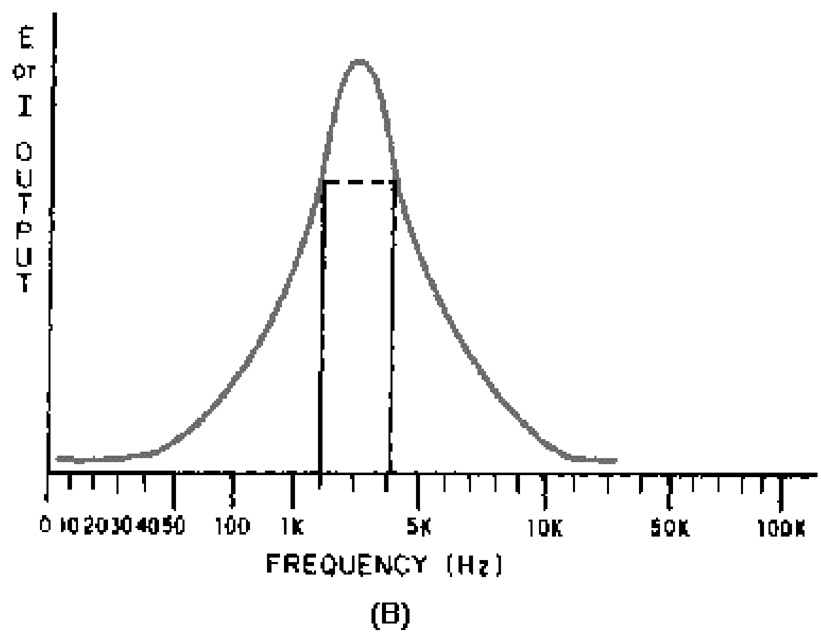


Figure 2-3B.—Frequency-response curves for Q3.

FACTORS AFFECTING FREQUENCY RESPONSE OF AN AMPLIFIER

In chapter 1 of this module, the fact was mentioned that an audio amplifier is limited in its frequency response. Now you will see why this is true.

You should recall that the frequency response of an a.c. circuit is limited by the reactive elements (capacitance and inductance) in the circuit. As you know, this is caused by the fact that the capacitive and inductive reactances vary with the frequency. In other words, the value of the reactance is determined, in part, by frequency. Remember the formulas:

$$X_C = \frac{1}{2\pi fC}$$

$$X_L = 2\pi fL$$

If you ignore the amplifying device (transistor, electron tube, etc.), and if the amplifier circuit is made up of resistors only, there should be no limits to the frequency response. In other words, a totally resistive circuit would have no frequency limits. However, there is no such thing as a totally resistive circuit because circuit components almost always have some reactance. In addition to the reactance of other components in the circuit, most amplifiers use RC coupling. This means that a capacitor is used to couple the signal in to and out of the circuit. There is also a certain amount of capacitance and inductance in the wiring of the circuit. The end result is that all circuits are reactive. To illustrate this point, figure 2-4 shows amplifier circuits with the capacitance and inductance of the wiring represented as "phantom" capacitors and inductors. The reactances of the capacitors (X_C) and the inductors (X_L) are shown as "phantom" variable resistors. View (A) shows the circuit with a low-frequency input signal, and view (B) shows the circuit with a high-frequency input signal.

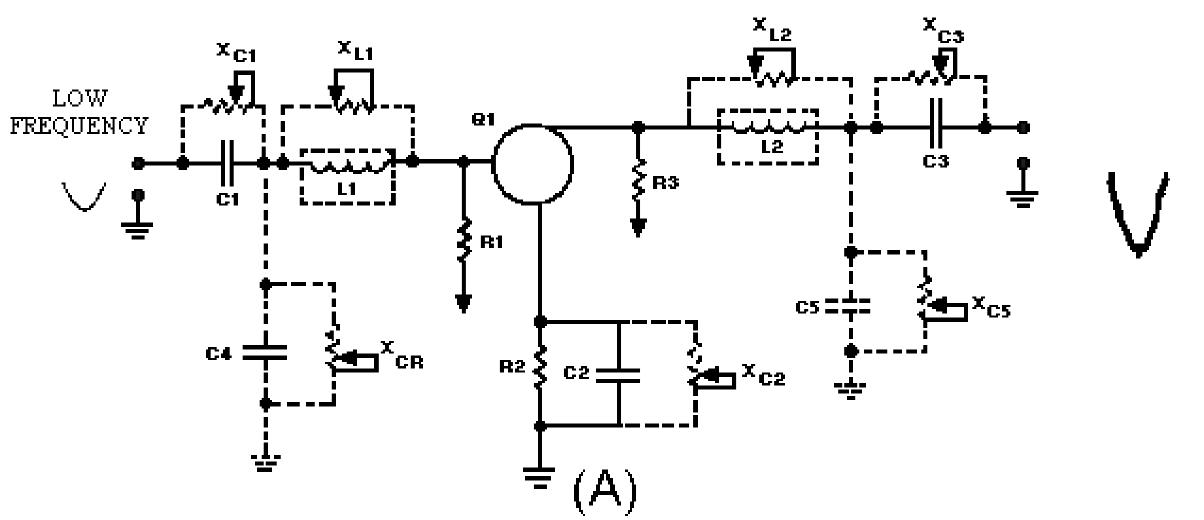


Figure 2-4A.—Amplifiers showing reactive elements and reactance.

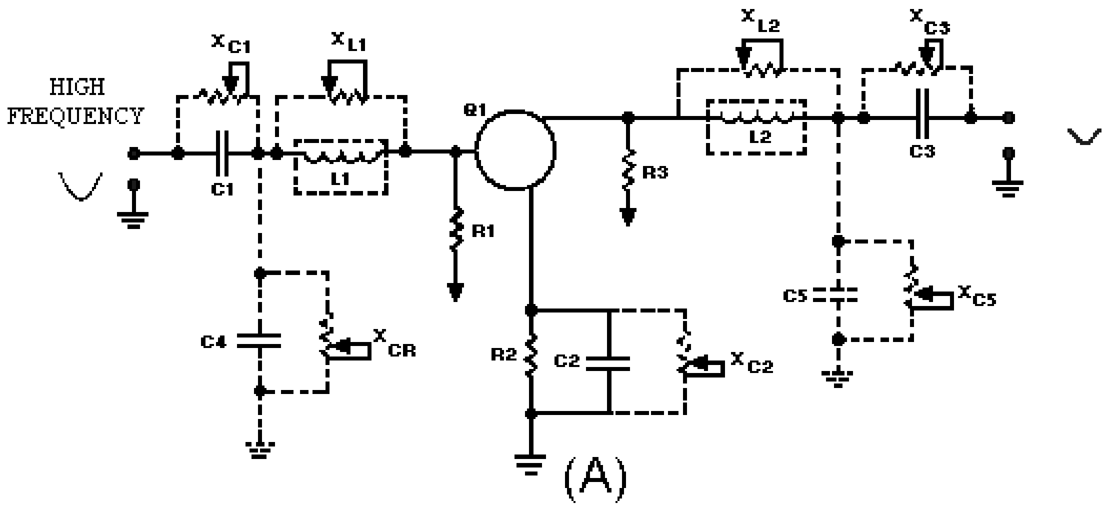


Figure 2-4B.—Amplifiers showing reactive elements and reactance.

The actual circuit components are: C1, C2, C3, R1, R2, R3, and Q1. C1 is used to couple the input signal. R1 develops the input signal. R2, the emitter resistor, is used for proper biasing and temperature stability. C2 is a decoupling capacitor for R2. R3 develops the output signal. C3 couples the output signal to the next stage. Q1 is the amplifying device.

The phantom circuit elements representing the capacitance and inductance of the wiring are: L1, L2, C4, and C5. L1 represents the inductance of the input wiring. L2 represents the inductance of the output wiring. C4 represents the capacitance of the input wiring. C5 represents the capacitance of the output wiring.

In view (A) the circuit is shown with a low-frequency input signal. Since the formulas for capacitive reactance and inductive reactance are:

$$X_C = \frac{1}{2\pi fC}$$

$$X_L = 2\pi fL$$

You should remember that if frequency is low, capacitive reactance will be high and inductive reactance will be low. This is shown by the position of the variable resistors that represent the reactances. Notice that X_{L1} and X_{L2} are low; therefore, they do not "drop" very much of the input and output signals. X_{C4} and X_{C5} are high; these reactances tend to "block" the input and output signals and keep them from going to the power supplies (V_{BB} and V_{CC}). Notice that the output signal is larger in amplitude than the input signal.

Now look at view (B). The input signal is a high-frequency signal. Now X_C is low and X_L is high. X_{L1} and X_{L2} now drop part of the input and output signals. At the same time X_{C4} and X_{C5} tend to "short" or "pass" the input and output signals to signal ground. The net effect is that both the input and output signals are reduced. Notice that the output signal is smaller in amplitude than the input signal.

Now you can see how the capacitance and inductance of the wiring affect an amplifier, causing the output of an amplifier to be less for high-frequency signals than for low-frequency signals.

In addition to the other circuit components, an amplifying device (transistor or electronic tube), itself, reacts differently to high frequencies than it does to low frequencies. In earlier *NEETS* modules you were told that transistors and electronic tubes have interelectrode capacitance. Figure 2-5 shows a portion of the interelectrode capacitance of a transistor and the way in which this affects high- and low-frequency signals.

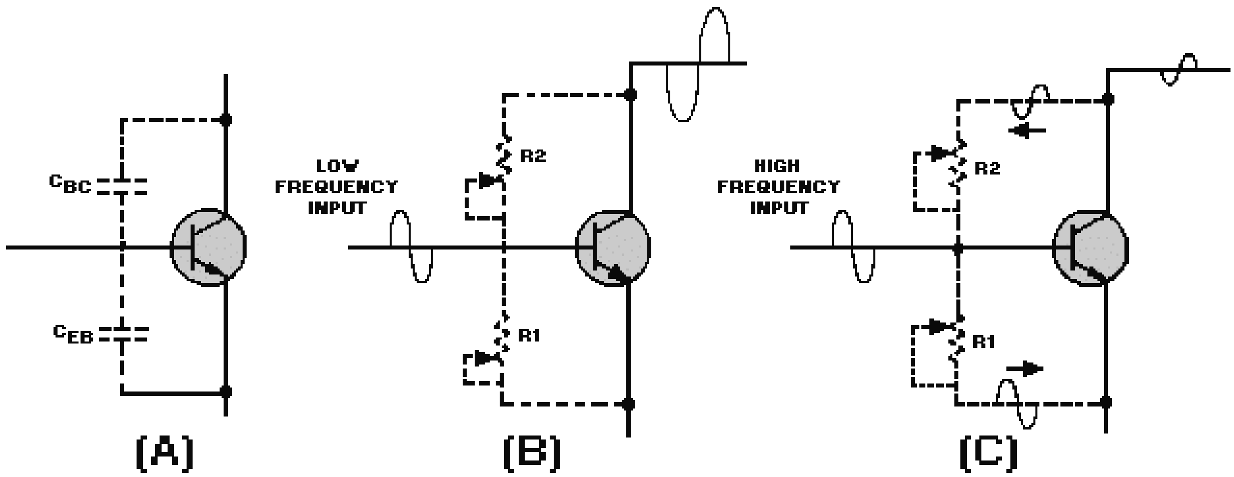


Figure 2-5.—Interelectrode capacitance of a transistor.

In view (A) a transistor is shown with phantom capacitors connected to represent the interelectrode capacitance. C_{EB} represents the emitter-to-base capacitance. C_{BC} represents the base-to-collector capacitance.

For simplicity, in views (B) and (C) the capacitive reactance of these capacitors is shown by variable resistors R1 (for C_{EB}) and R2 (for C_{BC}). View (B) shows the reactance as high when there is a low-frequency input signal. In this case there is very little effect from the reactance on the transistor. The transistor amplifies the input signal as shown in view (B). However, when a high-frequency input signal is applied to the transistor, as in view (C), things are somewhat different. Now the capacitive reactance is low (as shown by the settings of the variable resistors). In this case, as the base of the transistor attempts to go positive during the first half of the input signal, a great deal of this positive signal is felt on the emitter (through R1). If both the base and the emitter go positive at the same time, there is no change in emitter-base bias and the conduction of the transistor will not change. Of course, a small amount of change does occur in the emitter-base bias, but not as much as when the capacitive reactance is higher (at low frequencies). As an output signal is developed in the collector circuit, part of this signal is fed back to the base through R2. Since the signal on the collector is 180 degrees out of phase with the base signal, this tends to drive the base negative. The effect of this is to further reduce the emitter-base bias and the conduction of the transistor.During the second half of the input signal, the same effect occurs although the polarity is reversed. The net effect is a reduction in the gain of the transistor as indicated by the small output signal. This decrease in the amplifier output at higher frequencies is caused by the interelectrode capacitance. (There are certain special cases in which the feedback signal caused by the interelectrode capacitance is in phase with the base signal. However, in most cases, the feedback caused by interelectrode capacitance is degenerative and is 180 degrees out of phase with the base signal as explained above.)

Q-4. What are the factors that limit the frequency response of a transistor amplifier?

Q-5. What type of feedback is usually caused by interelectrode capacitance?

Q-6. What happens to capacitive reactance as frequency increases?

Q-7. What happens to inductive reactance as frequency increases?

VIDEO AMPLIFIERS

As you have seen, a transistor amplifier is limited in its frequency response. You should also remember from chapter 1 that a VIDEO AMPLIFIER should have a frequency response of 10 hertz (10 Hz) to 6 megahertz (6 MHz). The question has probably occurred to you: How is it possible to "extend" the range of frequency response of an amplifier?

HIGH-FREQUENCY COMPENSATION FOR VIDEO AMPLIFIERS

If the frequency-response range of an audio amplifier must be extended to 6 megahertz (6 MHz) for use as a video amplifier, some means must be found to overcome the limitations of the audio amplifier. As you have seen, the capacitance of an amplifier circuit and the interelectrode capacitance of the transistor (or electronic tube) cause the higher frequency response to be limited.

In some ways capacitance and inductance can be thought of as opposites. As stated before, as frequency increases, capacitive reactance decreases, and inductive reactance increases. Capacitance opposes changes in voltage, and inductance opposes changes in current. Capacitance causes current to lead voltage, and inductance causes voltage to lead current.

Since frequency affects capacitive reactance and inductive reactance in opposite ways, and since it is the capacitive reactance that causes the problem with high-frequency response, inductors are added to an amplifier circuit to improve the high-frequency response. This is called HIGH-FREQUENCY COMPENSATION. Inductors (coils), when used for high-frequency compensation, are called PEAKING COILS. Peaking coils can be added to a circuit so they are in series with the output signal path or in parallel to the output signal path. Instead of only in series or parallel, a combination of peaking coils in series and parallel with the output signal path can also be used for high-frequency compensation.

As in all electronic circuits, nothing comes free. The use of peaking coils WILL increase the frequency response of an amplifier circuit, but it will ALSO lower the gain of the amplifier.

Series Peaking

The use of a peaking coil in series with the output signal path is known as SERIES PEAKING. Figure 2-6 shows a transistor amplifier circuit with a series peaking coil. In this figure, R1 is the input-signal-developing resistor. R2 is used for bias and temperature stability of Q1. C1 is the bypass capacitor for R2. R3 is the load resistor for Q1 and develops the output signal. C2 is the coupling capacitor which couples the output signal to the next stage. "Phantom" capacitor C_{OUT} represents the output capacitance of the circuit, and "phantom" capacitor C_{IN} represents the input capacitance of the next stage.

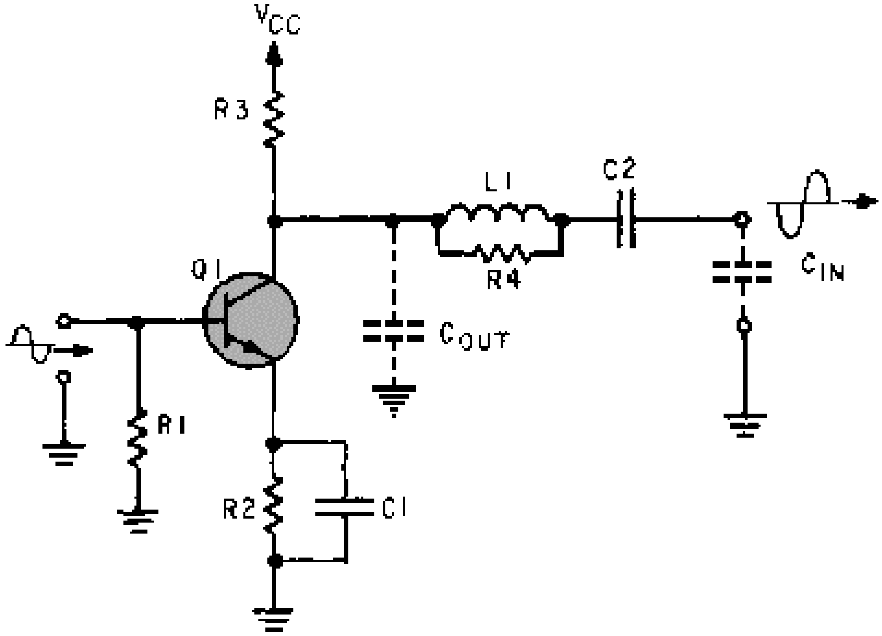


Figure 2-6.—Series peaking coil.

You know that the capacitive reactance of C_{OUT} and C_{IN} will limit the high-frequency response of the circuit. L1 is the series peaking coil. It is in series with the output-signal path and isolates C_{OUT} from C_{IN}. R4 is called a "swamping" resistor and is used to keep L1 from overcompensating at a narrow range of frequencies. In other words, R4 is used to keep the frequency-response curve flat. If R4 were not used with L1, there could be a "peak" in the frequency-response curve. (Remember, L1 is called a peaking coil.)

Shunt Peaking

If a coil is placed in parallel (shunt) with the output signal path, the technique is called SHUNT PEAKING. Figure 2-7 shows a circuit with a shunt peaking coil. With the exceptions of the "phantom" capacitor and the inductor, the components in this circuit are the same as those in figure 2-6. R1 is the input-signal-developing resistor. R2 is used for bias and temperature stability. C1 is the bypass capacitor for R2. R3 is the load resistor for Q1 and develops the output signal. C2 is the coupling capacitor which couples the output signal to the next stage.

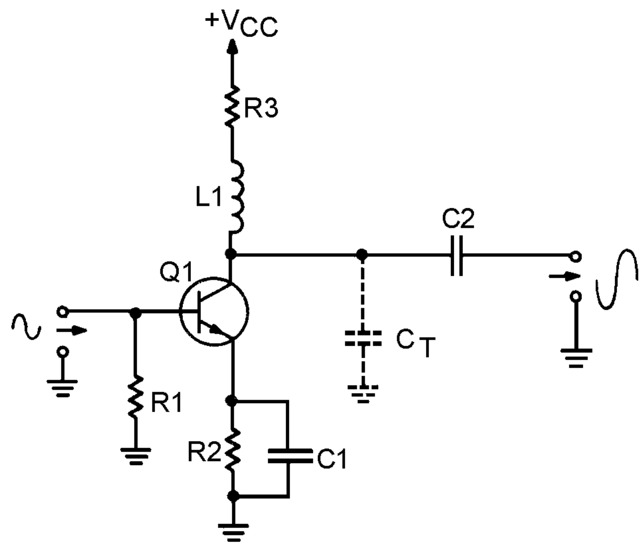


Figure 2-7.—Shunt peaking coil.

The "phantom" capacitor, C_T, represents the total capacitance of the circuit. Notice that it tends to couple the output signal to ground.

L1 is the shunt peaking coil. While it is in series with the load resistor (R3), it is in parallel (shunt) with the output-signal path.

Since inductive reactance increases as frequency increases, the reactance of L1 develops more output signal as the frequency increases. At the same time, the capacitive reactance of C_T is decreasing as frequency increases. This tends to couple more of the output signal to ground. The increased inductive reactance counters the effect of the decreased capacitive reactance and this increases the high-frequency response of the amplifier.

Combination Peaking

You have seen how a series peaking coil isolates the output capacitance of an amplifier from the input capacitance of the next stage. You have also seen how a shunt peaking coil will counteract the effects of the total capacitance of an amplifier. If these two techniques are used together, the combination is more effective than the use of either one alone. The use of both series and shunt peaking coils is known as COMBINATION PEAKING. An amplifier circuit with combination peaking is shown in figure 2-8. In figure 2-8 the peaking coils are L1 and L2. L1 is a shunt peaking coil, and L2 is a series peaking coil.

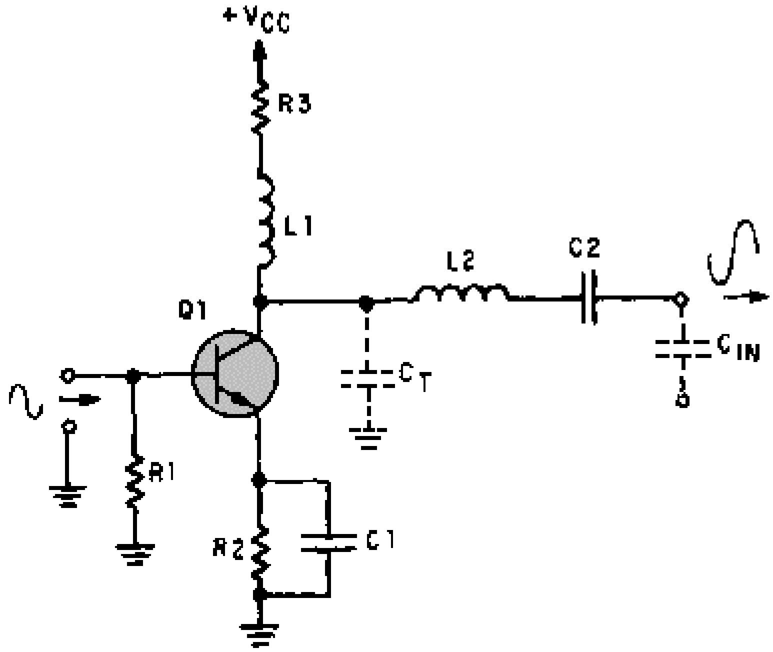


Figure 2-8.—Combination peaking.

The "phantom" capacitor C_T represents the total capacitance of the amplifier circuit. "Phantom" capacitor C_{IN} represents the input capacitance of the next stage. Combination peaking will easily allow an amplifier to have a high-frequency response of 6 megahertz (6 MHz).

Q-8. What is the major factor that limits the high-frequency response of an amplifier circuits?

Q-9. What components can be used to increase the high-frequency response of an amplifier?

Q-10. What determines whether these components are considered series or shunt?

Q-11. What is the arrangement of both series and shunt components called?

LOW-FREQUENCY COMPENSATION FOR VIDEO AMPLIFIERS

Now that you have seen how the high-frequency response of an amplifier can be extended to 6 megahertz (6 MHz), you should realize that it is only necessary to extend the low-frequency response to 10 hertz (10 Hz) in order to have a video amplifier.

Once again, the culprit in low-frequency response is capacitance (or capacitive reactance). But this time the problem is the coupling capacitor between the stages.

At low frequencies the capacitive reactance of the coupling capacitor (C2 in figure 2-8) is high. This high reactance limits the amount of output signal that is coupled to the next stage. In addition, the RC network of the coupling capacitor and the signal-developing resistor of the next stage cause a phase shift in the output signal. (*Refer to NEETS, Module 2, for a discussion of phase shifts in RC networks.) Both of* these problems (poor low-frequency response and phase shift) can be solved by adding a parallel RC network in series with the load resistor. This is shown in figure 2-9.

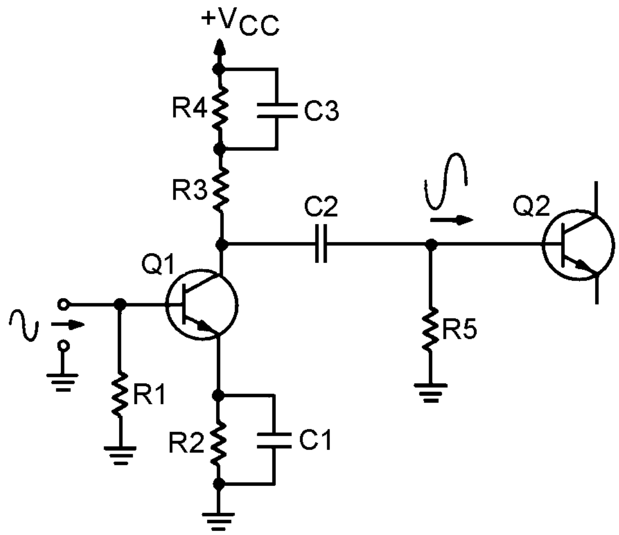


Figure 2-9.—Low frequency compensation network.

The complete circuitry for Q2 is not shown in this figure, as the main concern is the signal-developing resistor (R5) for Q2. The coupling capacitor (C2) and the resistor (R5) limit the low-frequency response of the amplifier and cause a phase shift. The amount of the phase shift will depend upon the amount of resistance and capacitance. The RC network of R4 and C3 compensates for the effects of C2 and R5 and extends the low-frequency response of the amplifier.

At low frequencies, R4 adds to the load resistance (R3) and increases the gain of the amplifier. As frequency increases, the reactance of C3 decreases. C3 then provides a path around R4 and the gain of the transistor decreases. At the same time, the reactance of the coupling capacitor (C2) decreases and more signal is coupled to Q2.

Because the circuit shown in figure 2-9 has no high-frequency compensation, it would not be a very practical video amplifier.

TYPICAL VIDEO-AMPLIFIER CIRCUIT

There are many different ways in which video amplifiers can be built. The particular configuration of a video amplifier depends upon the equipment in which the video amplifier is used. The circuit shown in figure 2-10 is only one of many possible video-amplifier circuits. Rather than reading about what each component does in this circuit, you can see how well you have learned about video amplifiers by answering the following questions. You should have no problem identifying the purpose of the components because similar circuits have been explained to you earlier in the text.

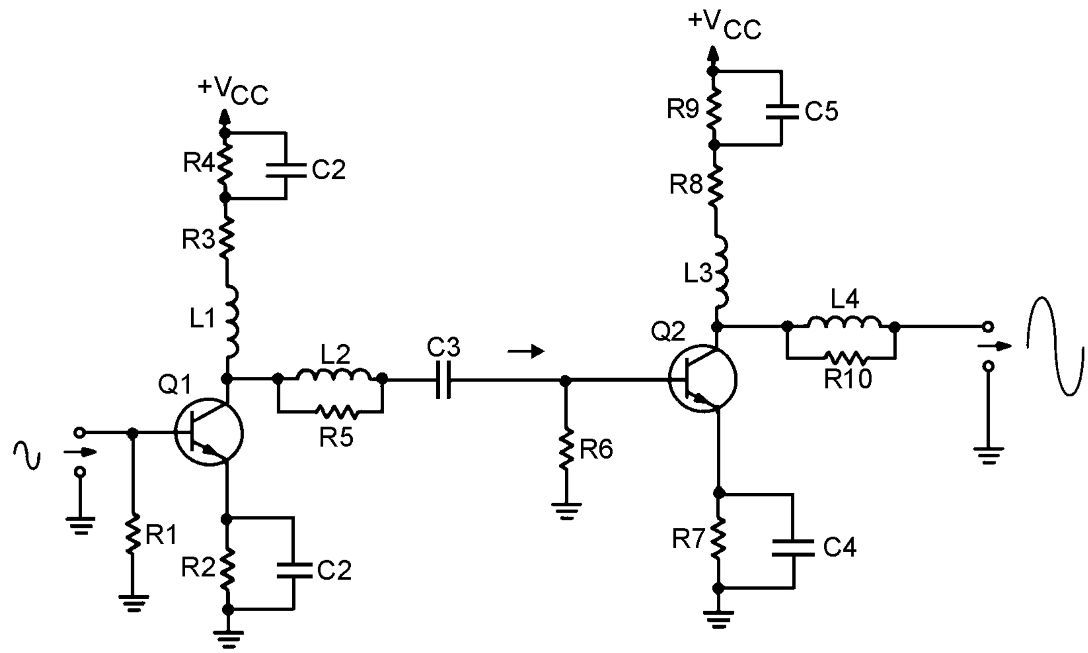


Figure 2-10.—Video amplifier circuit.

The following questions refer to figure 2-10.

Q-12. What component in an amplifier circuit tends to limit the low-frequency response of the amplifier?

Q-13. What is the purpose of L3?

Q-14. What is the purpose of C1?

Q-15. What is the purpose of R4?

Q-16. What is the purpose of L2?

Q-17. What is the purpose of R5?

Q-18. What component(s) is/are used for high-frequency compensation for Q1?

Q-19. What component(s) is/are used for low-frequency compensation for Q2?

RADIO-FREQUENCY AMPLIFIERS

Now that you have seen the way in which a broadband, or video, amplifier can be constructed, you may be wondering about radio-frequency (rf) amplifiers. Do they use the same techniques? Are they just another type of broadband amplifier?

The answer to both questions is "no." Radio-frequency amplifiers use different techniques than video amplifiers and are very different from them.

Before you study the specific techniques used in rf amplifiers, you should review some information on the relationship between the input and output impedance of an amplifier and the gain of the amplifier stage.

AMPLIFIER INPUT/OUTPUT IMPEDANCE AND GAIN

You should remember that the gain of a stage is calculated by using the input and output signals. The formula used to calculate the gain of a stage is:

$$\text{gain} = \frac{\text{Output Signal}}{\text{Input Signal}}$$

Voltage gain is calculated using input and output voltage; current gain uses input and output current; and power gain uses input and output power. For the purposes of our discussion, we will only be concerned with voltage gain.

Figure 2-11 shows a simple amplifier circuit with the input- and output-signal-developing impedances represented by variable resistors. In this circuit, C1 and C2 are the input and output coupling capacitors. R1 represents the impedance of the input circuit. R2 represents the input-signal-developing impedance, and R3 represents the output impedance.

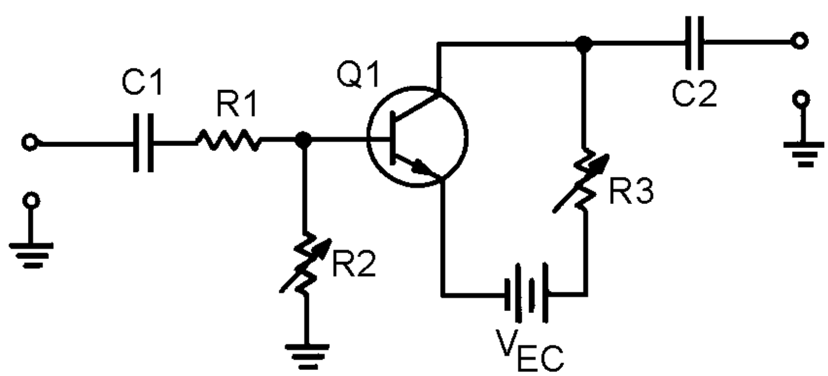


Figure 2-11.—Variable input and output impedances.

R1 and R2 form a voltage-divider network for the input signal. When R2 is increased in value, the input signal to the transistor (Q1) increases. This causes a larger output signal, and the gain of the stage increases.

Now look at the output resistor, R3. As R3 is increased in value, the output signal increases. This also increases the gain of the stage.

As you can see, increasing the input-signal-developing impedance, the output impedance, or both will increase the gain of the stage. Of course there are limits to this process. The transistor must not be overdriven with too high an input signal or distortion will result.

With this principle in mind, if you could design a circuit that had maximum impedance at a specific frequency (or band of frequencies), that circuit could be used in an rf amplifier. This FREQUENCY-DETERMINING NETWORK could be used as the input-signal-developing impedance, the output impedance, or both. The rf amplifier circuit would then be as shown in figure 2-12.

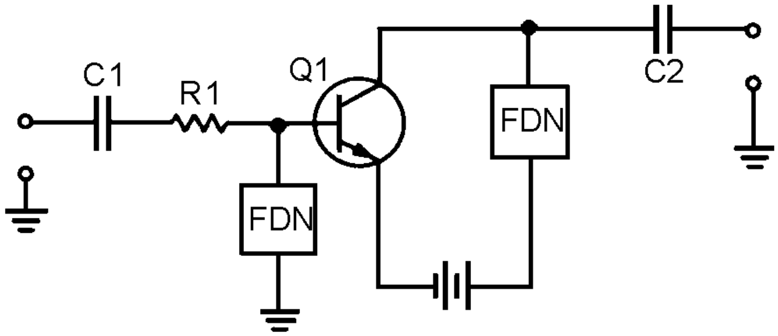


Figure 2-12.—Semiblock diagram of rf amplifier.

In this "semi-block" diagram, C1 and C2 are the input and output coupling capacitors. R1 represents the impedance of the input circuit. The blocks marked FDN represent the frequency-determining networks. They are used as input-signal-developing and output impedances for Q1.

FREQUENCY-DETERMINING NETWORK FOR AN RF AMPLIFIER

What kind of circuit would act as a frequency-determining network? In general, a frequency-determining network is a circuit that provides the desired response at a particular frequency. This response could be maximum impedance or minimum impedance; it all depends on how the frequency-determining network is used. You will see more about frequency-determining networks in *NEETS, Module 9—Introduction to Wave-Generation and Shaping Circuits*. As you have seen, the frequency-determining network needed for an rf amplifier should have maximum impedance at the desired frequency.

Before you are shown the actual components that make up the frequency-determining network for an rf amplifier, look at figure 2-13, which is a simple parallel circuit. The resistors in this circuit are variable and are connected together (ganged) in such a way that as the resistance of R1 increases, the resistance of R2 decreases, and vice versa.

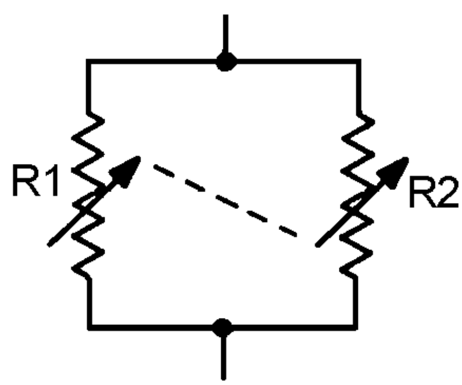


Figure 2-13.—Parallel variable resistors (ganged).

If each resistor has a range from 0 to 200 ohms, the following relationship will exist between the individual resistances and the resistance of the network (R_T). (All values are in ohms, R_T rounded off to two decimal places. These are selected values; there are an infinite number of possible combinations.)

R1	R2	RT
0	200	0.00
10	190	9.50
25	175	21.88
50	150	37.50
75	125	46.88
100	100	50.00
125	75	46.88
150	50	37.50
175	25	21.88
190	10	9.50
200	0	0.00

As you can see, this circuit has maximum resistance (R_T) when the individual resistors are of equal value. If the variable resistors represented impedances and if components could be found that varied their impedance in the same way as the ganged resistors in figure 2-13, you would have the frequency-determining network needed for an rf amplifier.

There are components that will vary their impedance (reactance) like the ganged resistors. As you know, the reactance of an inductor and a capacitor vary as frequency changes. As frequency increases, inductive reactance increases, and capacitive reactance decreases.

At some frequency, inductive and capacitive reactance will be equal. That frequency will depend upon the value of the inductor and capacitor. If the inductor and capacitor are connected as a parallel LC circuit, you will have the ideal frequency-determining network for an rf amplifier.

The parallel LC circuit used as a frequency-determining network is called a TUNED CIRCUIT. This circuit is "tuned" to give the proper response at the desired frequency by selecting the proper values of inductance and capacitance. A circuit using this principle is shown in figure 2-14 which shows an rf amplifier with parallel LC circuits used as frequency-determining networks. This rf amplifier will only be effective in amplifying the frequency determined by the parallel LC circuits.

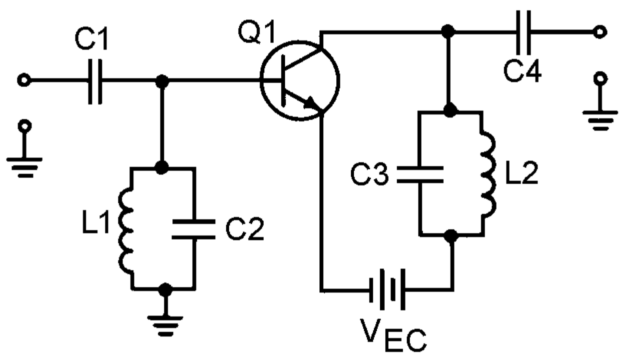


Figure 2-14.—Simple rf amplifier.

In many electronic devices, such as radio or television receivers or radar systems, a particular frequency must be selected from a band of frequencies. This could be done by using a separate rf amplifier for each frequency and then turning on the appropriate rf amplifier. It would be more efficient if a single rf amplifier could be "tuned" to the particular frequency as that frequency is needed. This is what happens when you select a channel on your television set or tune to a station on your radio. To accomplish this "tuning," you need only change the value of inductance or capacitance in the parallel LC circuits (tuned circuits).

In most cases, the capacitance is changed by the use of variable capacitors. The capacitors in the input and output portions of all the rf amplifier stages are ganged together in order that they can all be changed at one time with a single device, such as the tuning dial on a radio. (This technique will be shown on a schematic a little later in this chapter.)

Q-20. If the input-signal-developing impedance of an amplifier is increased, what is the effect on the gain?

Q-21. If the output impedance of an amplifier circuit is decreased, what is the effect on the gain?

Q-22. What is the purpose of a frequency-determining network in an rf amplifier?

Q-23. Can a parallel LC circuit be used as the frequency-determining network for an rf amplifier?

Q-24. How can the frequency be changed in the frequency-determining network?

RF AMPLIFIER COUPLING

Figure 2-14 and the other circuits you have been shown use capacitors to couple the signal in to and out of the circuit (C1 and C4 in figure 2-14). As you remember from chapter 1, there are also other methods of coupling signals from one stage to another. Transformer coupling is the most common method used to couple rf amplifiers. Transformer coupling has many advantages over RC coupling for rf amplifiers; for example, transformer coupling uses fewer components than capacitive coupling. It can also provide a means of increasing the gain of the stage by using a step-up transformer for voltage gain. If a current gain is required, a step-down transformer can be used.

You should also remember that the primary and secondary windings of a transformer are inductors. With these factors in mind, an rf amplifier could be constructed like the one shown in figure 2-15.

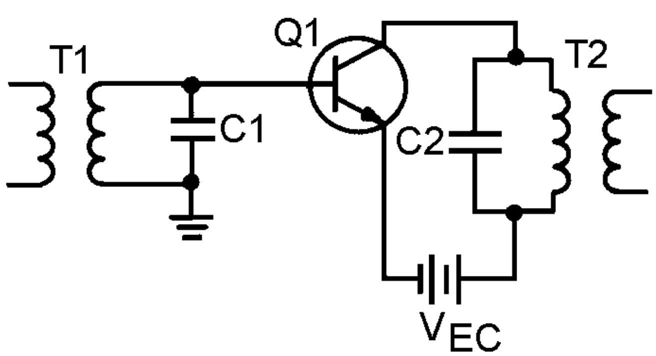


Figure 2-15.—Transformer-coupled rf amplifier.

In this circuit, the secondary of T1 and capacitor C1 form a tuned circuit which is the input-signal-developing impedance. The primary of T2 and capacitor C2 are a tuned circuit which acts as the output impedance of Q1. (Both T1 and T2 must be rf transformers in order to operate at rf frequencies.)

The input signal applied to the primary of T1 could come from the previous stage or from some input device, such as a receiving antenna. In either case, the input device would have a capacitor connected across a coil to form a tuned circuit. In the same way, the secondary of T2 represents the output of this circuit. A capacitor connected across the secondary of T2 would form a parallel LC network. This network could act as the input-signal-developing impedance for the next stage, or the network could represent some type of output device, such as a transmitting antenna.

The tuned circuits formed by the transformer and capacitors may not have the bandwidth required for the amplifier. In other words, the bandwidth of the tuned circuit may be too "narrow" for the requirements of the amplifier. (For example, the rf amplifiers used in television receivers usually require a bandwidth of 6 MHz.)

One way of "broadening" the bandpass of a tuned circuit is to use a swamping resistor. This is similar to the use of the swamping resistor that was shown with the series peaking coil in a video amplifier. A swamping resistor connected in parallel with the tuned circuit will cause a much broader bandpass. (This technique and the theory behind it are discussed in more detail in *NEETS, Module 9.)*

Another technique used to broaden the bandpass involves the amount of coupling in the transformers. For transformers, the term "coupling" refers to the amount of energy transferred from the primary to the secondary of the transformer. This depends upon the number of flux lines from the primary that intersect, or cut, the secondary. When more flux lines cut the secondary, more energy is transferred.

Coupling is mainly a function of the space between the primary and secondary windings. A transformer can be loosely coupled (having little transfer of energy), optimumly coupled (just the right amount of energy transferred), or overcoupled (to the point that the flux lines of primary and secondary windings interfere with each other).

Figure 2-16, (view A) (view B) (view C), shows the effect of coupling on frequency response when parallel LC circuits are made from the primary and secondary windings of transformers.

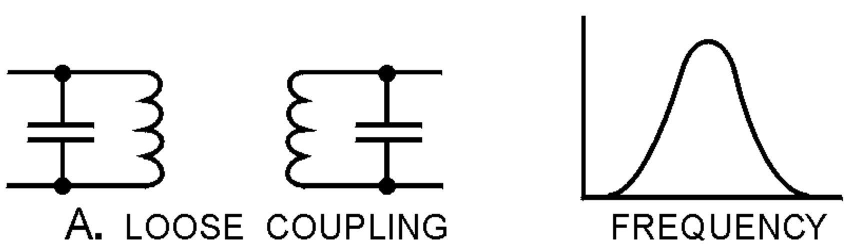


Figure 2-16A.—Effect of coupling on frequency response. LOOSE COUPLING

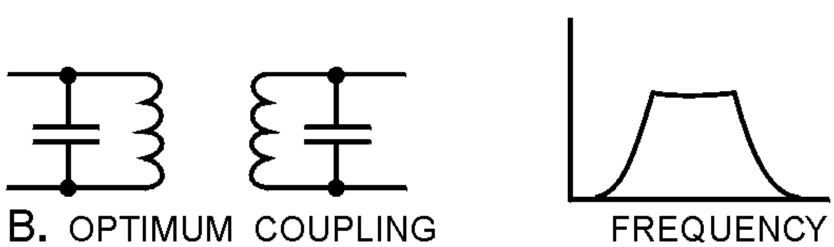


Figure 2-16B.—Effect of coupling on frequency response. OPTIMUM COUPLING

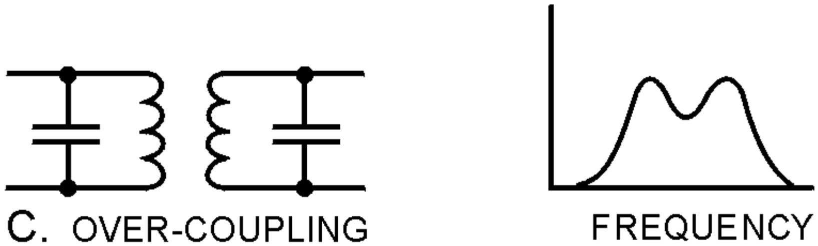


Figure 2-16C.—Effect of coupling on frequency response. OVER-COUPLING

In view (A) the transformer is loosely coupled; the frequency response curve shows a narrow bandwidth. In view (B) the transformer has optimum coupling; the bandwidth is wider and the curve is relatively flat. In view (C) the transformer is overcoupled; the frequency response curve shows a broad bandpass, but the curve "dips" in the middle showing that these frequencies are not developed as well as others in the bandwidth.

Optimum coupling will usually provide the necessary bandpass for the frequency-determining network (and therefore the rf amplifier). For some uses, such as rf amplifiers in a television receiver, the bandpass available from optimum coupling is not wide enough. In these cases, a swamping resistor (as mentioned earlier) will be used with the optimum coupling to broaden the bandpass.

COMPENSATION OF RF AMPLIFIERS

Now you have been shown the way in which an rf amplifier is configured to amplify a band of frequencies and the way in which an rf amplifier can be "tuned" for a particular band of frequencies. You have also seen some ways in which the bandpass of an rf amplifier can be adjusted. However, the frequencies at which rf amplifiers operate are so high that certain problems exist.

One of these problems is the losses that can occur in a transformer at these high frequencies. Another problem is with interelectrode capacitance in the transistor. The process of overcoming these problems is known as COMPENSATION.

Transformers in RF Amplifiers

As you recall from *NEETS, Module 1, t*he losses in a transformer are classified as copper loss, eddy-current loss, and hysteresis loss. Copper loss is not affected by frequency, as it depends upon the resistance of the winding and the current through the winding. Similarly, eddy-current loss is mostly a function of induced voltage rather than the frequency of that voltage. Hysteresis loss, however, increases as frequency increases.

Hysteresis loss is caused by the realignment of the magnetic domains in the core of the transformer each time the polarity of the magnetic field changes. As the frequency of the a.c. increases, the number of shifts in the magnetic field also increases (two shifts for each cycle of a.c.); therefore, the "molecular friction" increases and the hysteresis loss is greater. This increase in hysteresis loss causes the efficiency of the transformer (and therefore the amplifier) to decrease. The energy that goes into hysteresis loss is taken away from energy that could go into the signal.

RF TRANSFORMERS, specially designed for use with rf, are used to correct the problem of excessive hysteresis loss in the transformer of an rf amplifier. The windings of rf transformers are wound onto a tube of nonmagnetic material and the core is either powdered iron or air. These types of cores also reduce eddy-current loss.

Neutralization of RF Amplifiers

The problem of interelectrode capacitance in the transistor of an rf amplifier is solved by NEUTRALIZATION. Neutralization is the process of counteracting or "neutralizing" the effects of interelectrode capacitance.

Figure 2-17 shows the effect of the base-to-collector interelectrode capacitance in an rf amplifier. The "phantom" capacitor (C_{BC}) represents the interelectrode capacitance between the base and the collector of Q1. This is the interelectrode capacitance that has the most effect in an rf amplifier. As you can see, C_{BC} causes a degenerative (negative) feedback which decreases the gain of the amplifier. (There are some special cases in which C_{BC} can cause regenerative (positive) feedback. In this case, the technique described below will provide negative feedback which will accomplish the neutralization of the amplifier.)

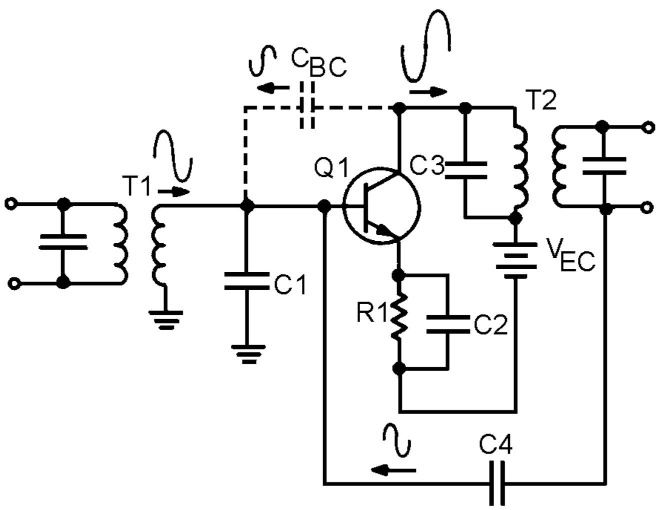


Figure 2-17.—Interelectrode capacitance in an rf amplifier.

As you may recall, unwanted degenerative feedback can be counteracted (neutralized) by using positive feedback. This is exactly what is done to neutralize an rf amplifier.

Positive feedback is accomplished by the use of a feedback capacitor. This capacitor must feed back a signal that is in phase with the signal on the base of Q1. One method of doing this is shown in figure 2-18.

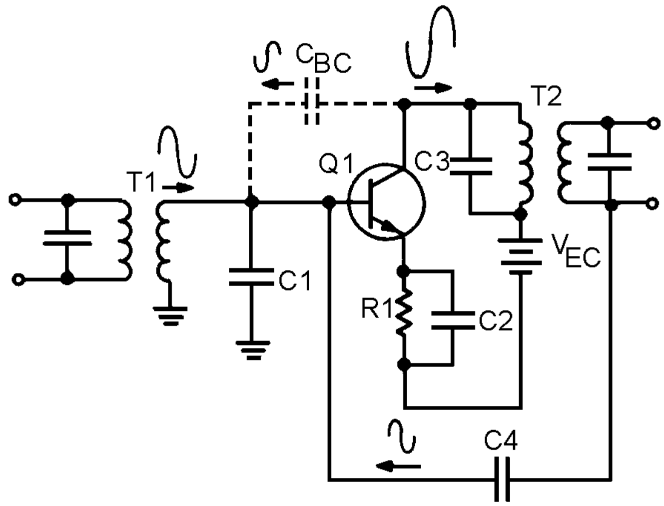


Figure 2-18.—Neutralized rf amplifier.

In figure 2-18, a feedback capacitor (C4) has been added to neutralize the amplifier. This solves the problem of unwanted degenerative feedback. Except for capacitor C4, this circuit is identical to the circuit shown in figure 2-17. (When C_{BC} causes regenerative feedback, C4 will still neutralize the amplifier. This is true because C4 always provides a feedback signal which is 180 degrees out of phase with the feedback signal caused by C_{BC}.)

Q-25. What is the most common form of coupling for an rf amplifier?

Q-26. What are two advantages of this type of coupling?

Q-27. If current gain is required from an rf amplifier, what type of component should be used as an output coupling element?

Q-28. What problem is caused in an rf amplifier by a loosely coupled transformer?

Q-29. How is this problem corrected?

Q-30. What problem is caused by overcoupling in a transformer?

Q-31. What method provides the widest bandpass?

Q-32. What two methods are used to compensate for the problems that cause low gain in an rf amplifier?

Q-33. What type of feedback is usually caused by the base-to-collector interelectrode capacitance?

Q-34. How is this compensated for?

TYPICAL RF AMPLIFIER CIRCUITS

As a technician, you will see many different rf amplifiers in many different pieces of equipment. The particular circuit configuration used for an rf amplifier will depend upon how that amplifier is used. In the final part of this chapter, you will be shown some typical rf amplifier circuits.

Figure 2-19 is the schematic diagram of a typical rf amplifier that is used in an AM radio receiver. In figure 2-19, the input circuit is the antenna of the radio (L1-a coil) which forms part of an LC circuit which is tuned to the desired station by variable capacitor C1. L1 is wound on the same core as L2, which couples the input signal through C2 to the transistor (Q1). R1 is used to provide proper bias to Q1 from the base power supply (V_{BB}). R2 provides proper bias to the emitter of Q1, and C3 is used to bypass R2. The primary of T1 and capacitor C4 form a parallel LC circuit which acts as the load for Q1. This LC circuit is tuned by C4, which is ganged to C1 allowing the antenna and the LC circuit to be tuned together. The primary of T1 is center-tapped to provide proper impedance matching with Q1.

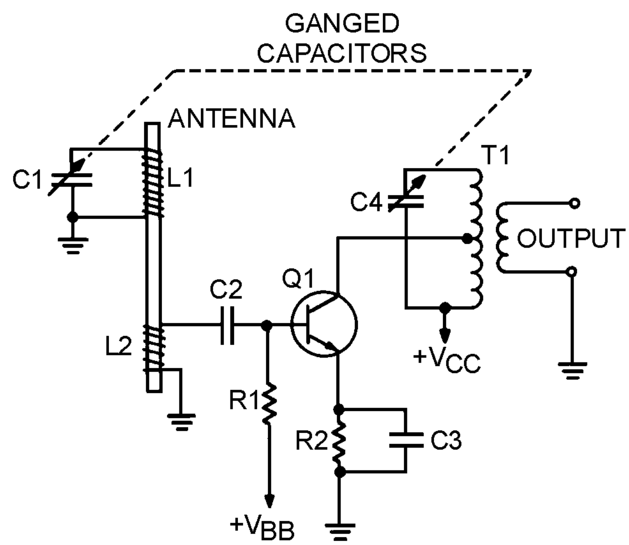


Figure 2-19.—Typical AM radio rf amplifier.

You may notice that no neutralization is shown in this circuit. This circuit is designed for the AM broadcast band (535 kHz - 1605 kHz).

At these relatively low rf frequencies the degenerative feedback caused by base-to-collector interelectrode capacitance is minor and, therefore, the amplifier does not need neutralization.

Figure 2-20 is a typical rf amplifier used in a vhf television receiver. The input-signal-developing circuit for this amplifier is made up of L1, C1, and C2. The inductor tunes the input-signal-developing circuit for the proper TV channel. (L1 can be switched out of the circuit and another inductor switched in to the circuit by the channel selector.) R1 provides proper bias to Q1 from the base supply voltage (V_{BB}). Q1 is the transistor. Notice that the case of Q1 (the dotted circle around the transistor symbol) is shown to be grounded. The case must be grounded because of the high frequencies (54 MHz - 217 MHz) used by the circuit. R2 provides proper bias from the emitter of Q1, and C3 is used to bypass R2. C5 and L2 are a parallel LC circuit which acts as the load for Q1. The LC circuit is tuned by L2 which is switched in to and out of the LC circuit by the channel selector. L3 and C6 are a parallel LC circuit which develops the signal for the next stage. The parallel LC circuit is tuned by L3 which is switched in to and out of the LC circuit by the channel selector along with L1 and L2. (L1, L2, and L3 are actually part of a bank of inductors. L1, L2, and L3 are in the circuit when the channel selector is on channel 2. For other channels, another group of three inductors would be used in the circuit.) R3 develops a signal which is fed through C4 to provide neutralization. This counteracts the effects of the interelectrode capacitance from the base to the collector of Q1. C7 is used to isolate the rf signal from the collector power supply (V_{CC}).

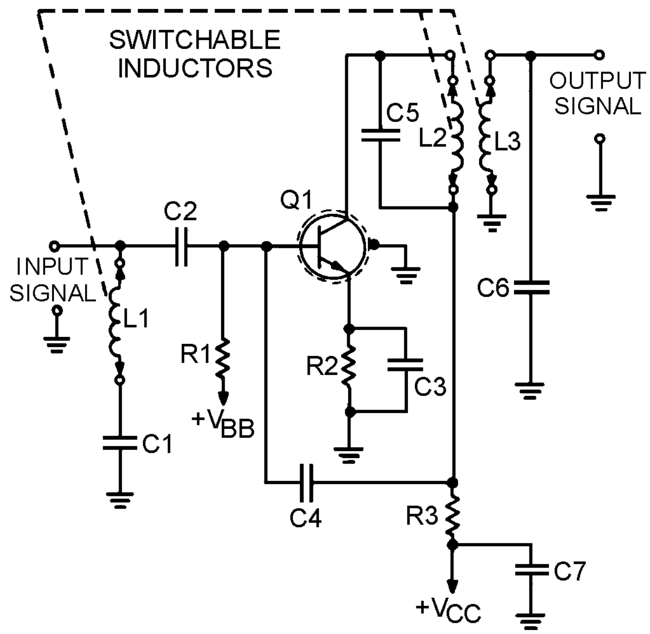


Figure 2-20.—Typical vhf television rf amplifier.

The following questions refer to figure 2-21.

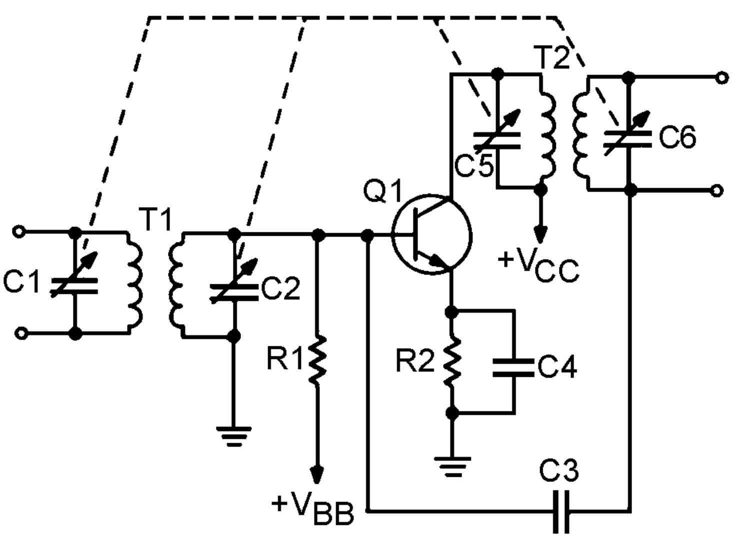


Figure 2-21.—Typical rf amplifier.

Q-35. What components form the input-signal-developing impedance for the amplifier?

Q-36. What is the purpose of R1?

Q-37. What is the purpose of R2?

Q-38. If C4 were removed from the circuit, what would happen to the output of the amplifier?

Q-39. What components form the load for Q1?

Q-40. How many tuned parallel LC circuits are shown in this schematic?

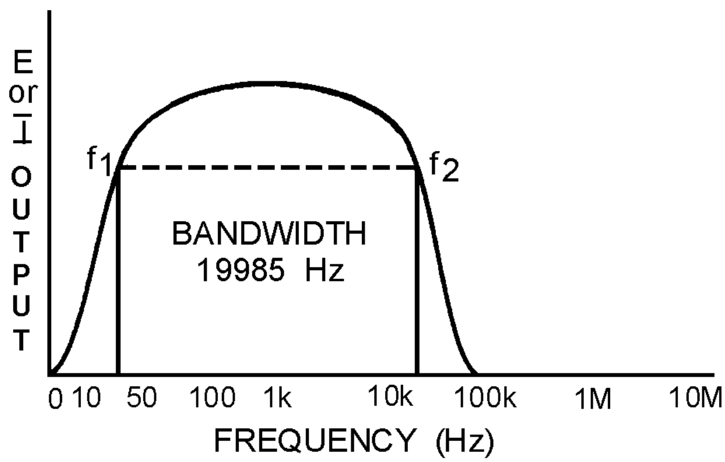
Q-41. What do the dotted lines connecting C1, C2, C5, and C6 indicate?

Q-42. What is the purpose of C3?

SUMMARY

This chapter has presented information on video and rf amplifiers. The information that follows summarizes the important points of this chapter.

A **FREQUENCY-RESPONSE CURVE** will enable you to determine the BANDWIDTH and the UPPER and LOWER FREQUENCY LIMITS of an amplifier.



The **BANDWIDTH** of an amplifier is determined by the formula:

$$BW = f_2 - f_1$$

Where:

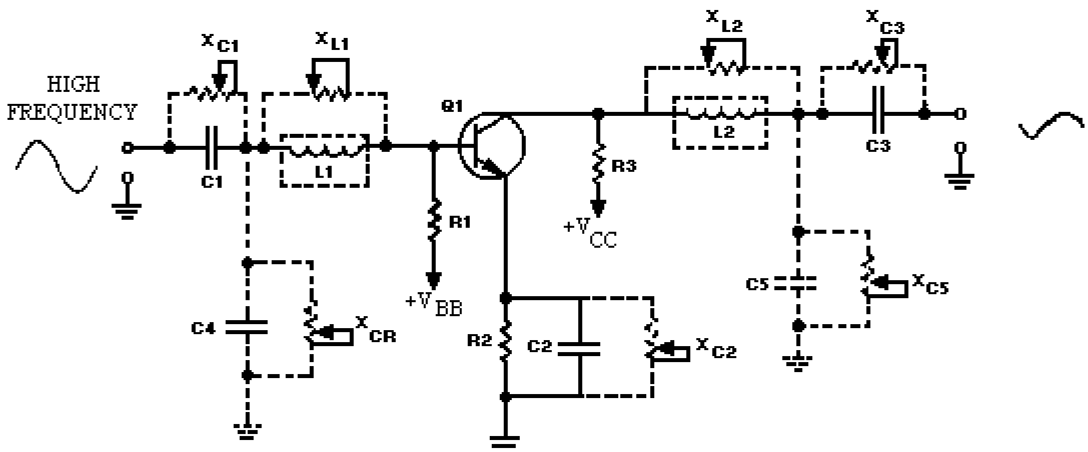
BW is the bandwidth

f_2 is the upper-frequency limit

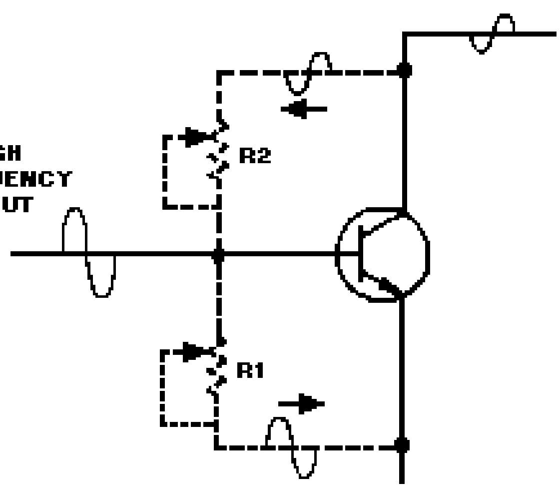
and

f_1 is the lower-frequency limit

The **UPPER-FREQUENCY RESPONSE** of an amplifier is limited by the inductance and capacitance of the circuit.



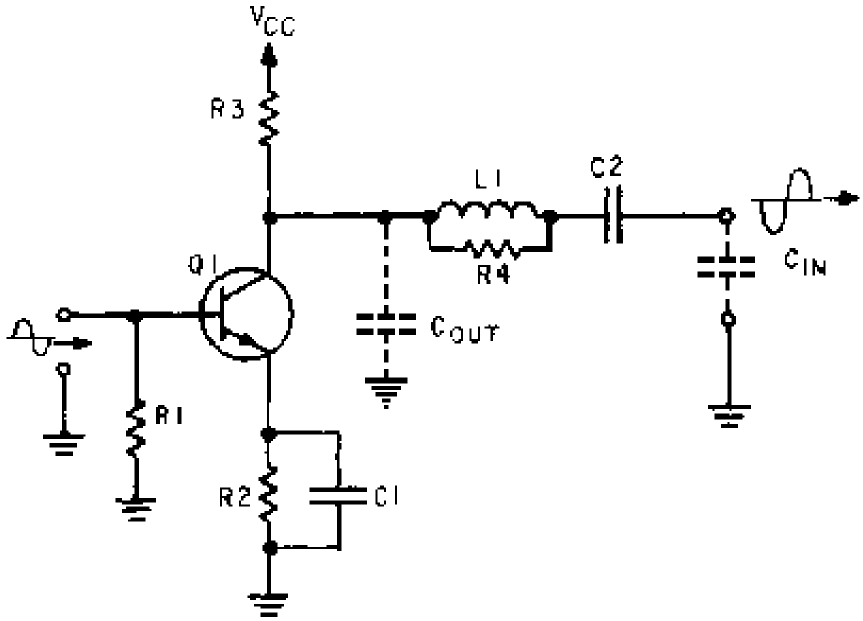
The **INTERELECTRODE CAPACITANCE** of a transistor causes DEGENERATIVE FEEDBACK at high frequencies.



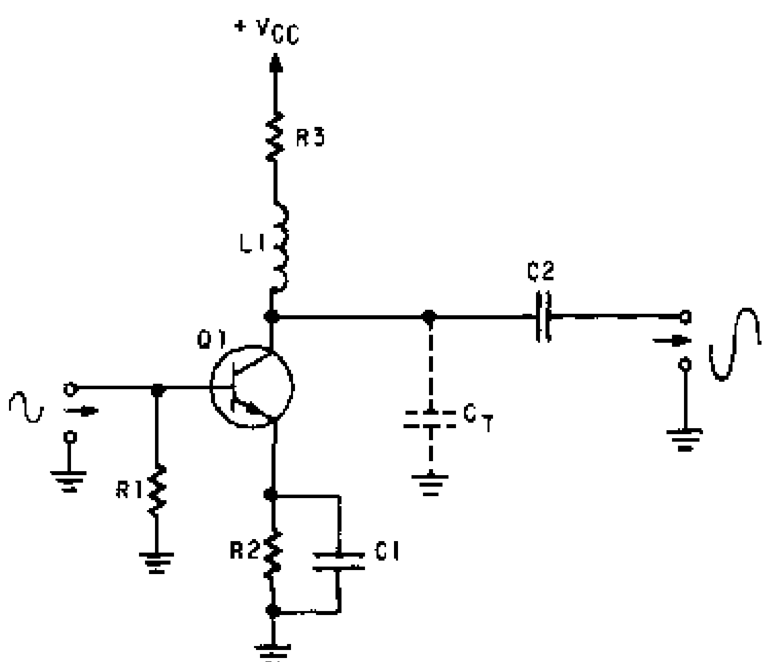
VIDEO AMPLIFIERS must have a frequency response of 10 hertz to 6 megahertz (10 Hz – 6 MHz). To provide this frequency response, both high- and low-frequency compensation must be used.

PEAKING COILS are used in video amplifiers to overcome the high-frequency limitations caused by the capacitance of the circuit.

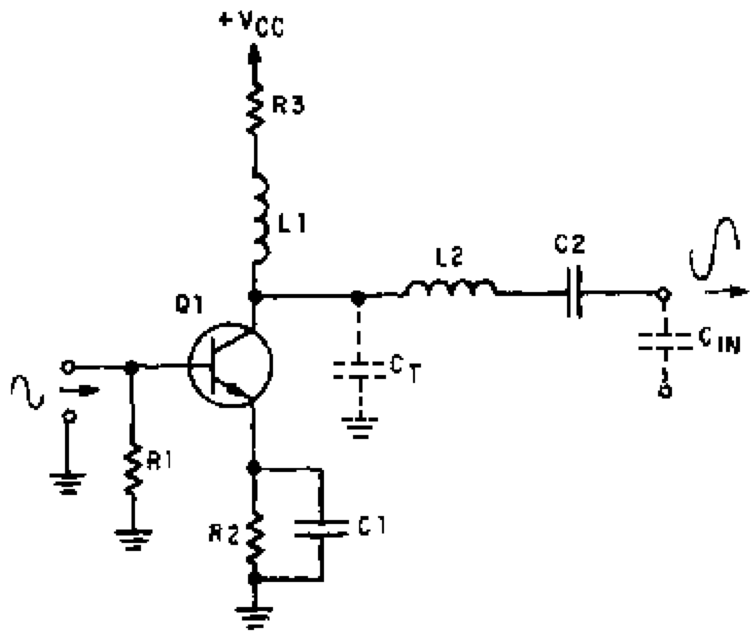
SERIES PEAKING is accomplished by a peaking coil in series with the output-signal path.



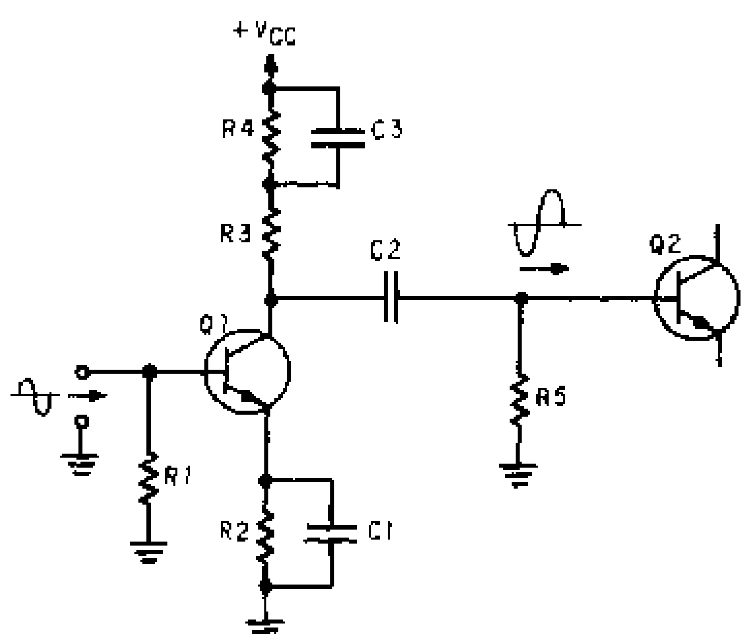
SHUNT PEAKING is accomplished by a peaking coil in parallel (shunt) with the output-signal path.



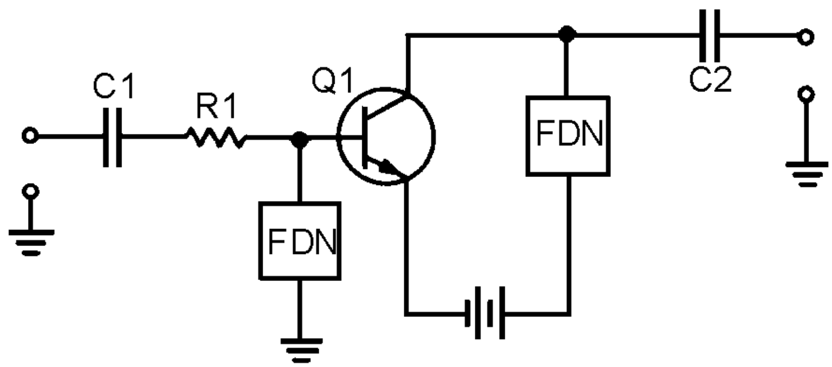
COMBINATION PEAKING is accomplished by using both series and shunt peaking.



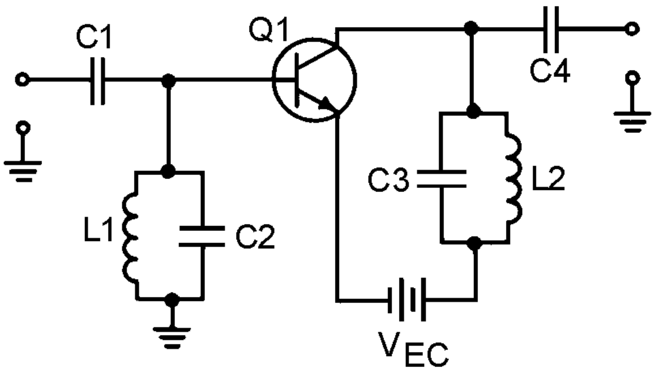
LOW-FREQUENCY COMPENSATION is accomplished in a video amplifier by the use of a parallel RC circuit in series with the load resistor.



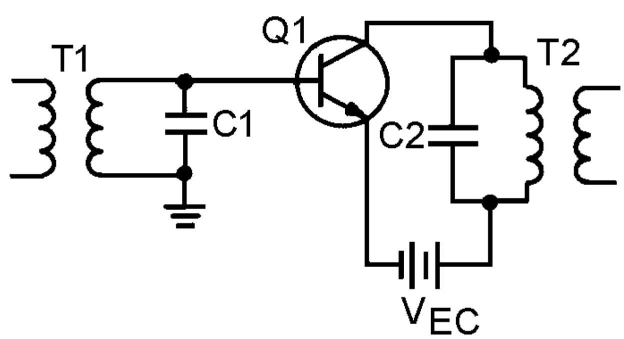
A **RADIO-FREQUENCY (RF) AMPLIFIER** uses FREQUENCY-DETERMINING NETWORKS to provide the required response at a given frequency.



The **FREQUENCY-DETERMINING NETWORK** in an rf amplifier provides maximum impedance at the desired frequency. It is a parallel LC circuit which is called a TUNED CIRCUIT.

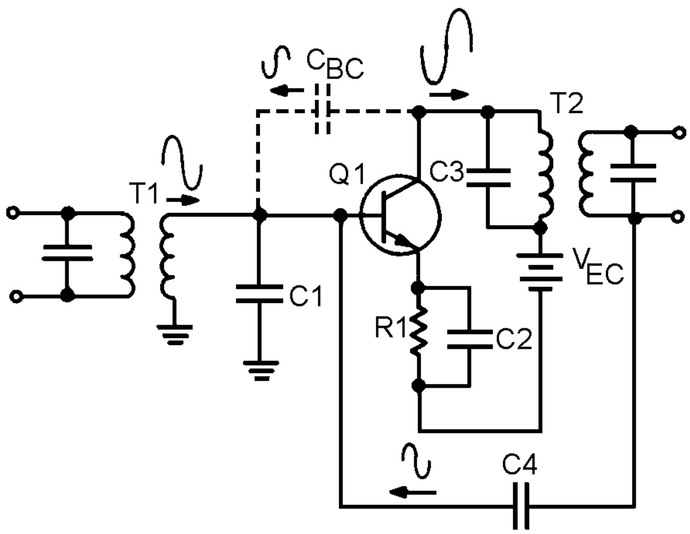


TRANSFORMER COUPLING is the most common form of coupling in rf amplifiers. This coupling is accomplished by the use of rf transformers as part of the frequency-determining network for the amplifier.



ADEQUATE BANDPASS is accomplished by optimum coupling in the rf transformer or by the use of a SWAMPING RESISTOR.

NEUTRALIZATION in an rf amplifier provides feedback (usually positive) to overcome the effects caused by the base-to-collector interelectrode capacitance.



ANSWERS TO QUESTIONS Q1. THROUGH Q42.

A-1. *The difference between the upper and lower frequency limits of an amplifier.*

A-2. *The half-power points of a frequency-response curve. The upper and lower limits of the band f frequencies for which the amplifier is most effective.*

A-3. *(A) f_2 = 80 kHz, f_1 = 30 kHz, BW = 50 kHz (B) f_2 = 4 kHz, f_1 = 2 kHz, BW = 2 kHz*

A-4. *The capacitance and inductance of the circuit and the interelectrode capacitance of the transistor.*

A-5. *Negative (degenerative) feedback.*

A-6. *It decreases.*

A-7. *It increases.*

A-8. *The capacitance of the circuit.*

A-9. *Peaking coils.*

A-10. *The relationship of the components to the output-signal path.*

A-11. *Combination peaking.*

A-12. *The coupling capacitor (C3).*

A-13. A shunt peaking coil for Q2.

A-14. A decoupling capacitor for the effects of R2.

A-15. A part of the low-frequency compensation network for Q1.

A-16. A series peaking coil for Q1.

A-17. A swamping resistor for L2.

A-18. L1, L2, and R5.

A-19. R9 and C5.

A-20. The gain increases.

A-21. The gain decreases.

A-22. To provide maximum impedance at the desired frequency.

A-23. Yes.

A-24. By changing the value.

A-25. Transformer coupling.

A-26. It uses fewer components than capacitive coupling and can provide an increase in gain.

A-27. A step-down transformer.

A-28. A too-narrow bandpass.

A-29. By using an optimumly-coupled transformer.

A-30. Low gain at the center frequency.

A-31. A swamping resistor in parallel with the tuned circuit.

A-32. RF transformers are used and the transistor is neutralized.

A-33. Degenerative or negative.

A-34. By neutralization such as the use of a capacitor to provide regenerative (positive) feedback.

A-35. C2 and the secondary of T1.

A-36. R1 provides the proper bias to the base of Q1 from V_{BB}.

A-37. R2 provides the proper bias to the emitter of Q1.

A-38. The output would decrease. (C4 decouples R2 preventing degenerative feedback from R2.)

A-39. C5 and the primary of T2.

A-40. Four.

A-41. *The dotted lines indicate that these capacitors are "ganged" and are tuned together with a single control.*

A-42. *C3 provides neutralization for Q1.*